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MONTANA LARGE APERTURE SEISMIC ARRAY

LASA

FORD AEROSPACE &
COMMUNICATIONS CORPORATION
214 NORTH 30TH STREET
BILLINGS, MONTANA
Engineering Services Div

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Maintenance activities at both the data and maintenance centers are discussed.

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MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

PROJECT VT 6708

CONTRACT F08606-76-C-0005

1 JANUARY 1976 - 30 SEPTEMBER 1976

29 October 1976

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Billings, Montana

MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

Report No. 2126-76-85

29 October 1976

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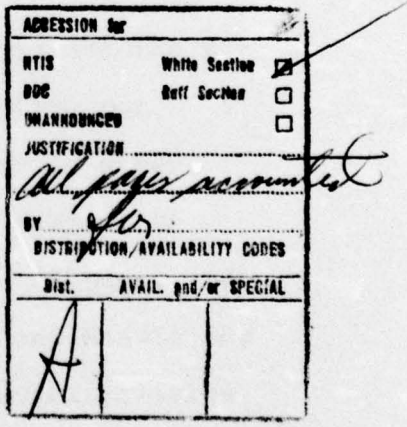

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ABSTRACT

The continued operation, maintenance, and array improvement activities at the Montana LASA during the period between January 1 and September 30, 1976, are described. Array operations including the preparation of daily teleseismic event reports are detailed. Results of the seismic event processing effort are reported. Seismograph system performance measurements are presented. Program maintenance for the PDP-7 computer system is indicated. Maintenance activities at both the data and maintenance centers are discussed.

ACKNOWLEDGEMENT

Aeronutronic Ford wishes to recognize the excellent technical direction provided to the Montana LASA project during this contract period by Capt. Robert J. Woodward at the VELA Seismological Center.

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INTRODUCTION

This is the second semi-annual technical report of the activity by Aeronutronic Ford on the Montana Large Aperture Seismic Array (LASA), Project VELA T/6708, under contract F08606-76-C-0005.

The primary goal of this project is to operate and maintain the LASA in a manner which produces unique high quality seismic data for use by other government sponsored research projects.

The work described here began 1 January 1976 and continued through 30 September 1976.

The sections following in this report describe the operation of the various systems installed at the LASA, the performance measurements on the equipment, the teleseismic and near-regional event reporting, the PDP-7 computer programming, and the maintenance performed on the systems.

SECTION I

SEMI-ANNUAL SUMMARY OF EVENTS

This, second Semi-annual Technical Summary report, describes the activities at the Montana LASA during January through September 1976. These activities include the operation and maintenance of the systems installed both in the array and at the data center (LDC).

The LASA Processing System (LASAPS) operated continuously with the Seismic Data Analysis Center (SDAC) 95.6% of this nine-month period. System/360 failures and their correction accounted for the majority of the on-line interruptions (94.4%). Operation of the new LASAPS over the 4800-baud line is not as satisfactory as with the previous system over the 50 K-baud line, especially in the areas of operator communications and recognizing when the SDAC systems are on-line.

Digital recording of the array data by the PDP-7 computer continued on a full-time basis with the exception of an average 50-minute per day interruption for off-line program processing and system maintenance. The digital recordings were available from the LDC during the 60-day retention cycle before their reuse. Recordings of event periods since November 1, 1975, are still available at the LDC on edited tapes produced by the PDP-7 AUTO-EDIT system.

Teleseismic event processing using film recordings and on-line computer playouts were routinely performed with the average daily result of 12.4 events or phases reported to VSC. Also, periodic near regional and strip-mine blast listings added an

average of 6.4 events/day. Comparisons with USGS show our reported magnitudes only slightly higher (0.04 units ave) than the PDE's, our locations differing by about 5.8 degrees, and the 90% detection threshold of our reports at 4.97.

Equipment and facilities maintenance allowed the continued operation of the array in a manner similar to previous periods.

R. Matkins

SECTION II

OPERATIONS OF ALL LASA SYSTEMS

A. LASAPS OPERATIONS

The transcontinental data link between SDAC and the LDC has been on-line continuous at a 4800 baud rate for this reporting period. The known interruptions were: 1.8 hrs, 4.8 Kb line not operational; 110.6 hrs, LDC 360 corrective maintenance; 141.7 hrs, LDC 360 awaiting maintenance and parts; 21.1 hrs, LDC 360 halts and power outages; 10.6 hrs, LDC 360 preventive maintenance; and 3.7 hrs, LDC 360 shut-down due to other equipment outage. Since SDAC-LDC on-line data operations have included equipment/systems testing modes no attempt has been made to log SDAC operations.

Four test signals using sinewaves have replaced the three LP and the SP north-south horizontal seismometer signals at site D2 for this reporting period.

Operator communications with the SDAC continued to be our main problem with the LASAPS operation. Some of these problems may be related to testing at SDAC since many start-resume one second messages are received. There have been frequent restarts at SDAC request because of invalid data. Prior to these requests there are no indications of a problem at the LASAPS processor but the restarts appear to clear up the data communications with SDAC. Further, the ring on the telephone data set is barely audible in the normal LASA noise environment.

B. PDP-7 COMPUTER OPERATIONS

1. Data Recording

Maximum utilization of the PDP-7 computer for data

recording and event detection continues to be an important part of the Montana array operation. The LASA Inner Array Recording System (LIARS) which records at a 10 samples/sec and records only the 10 inner subarray sensors continued throughout this nine-month period except for brief interruptions of array off-line operations. Off-line operations totalled 160.8 hrs (2.45%) and downtine totalled 46.9 hrs (0.71%). Data recording covered 6353.3 hrs (96.61%).

2. Auto-Edit

The Auto-Edit program (Ref. 1) operated throughout a major portion of this period. Forty-five (45) master edit tapes now contain 4704 event periods from November 1, 1975 through September 13, 1976 for an average of 7.1 days/tape. A new version of Auto-Edit began on August 7, 1976, which codes the master tape header with type and seismic location of each event.

3. Event Detection

Automatic event detection at the LDC continued without any changes in its design. Event detection by the PDP-7 is used in the preparation of the daily teleseismic reports. All event detections that were too small to process or were classified "FORGET" have been added to bottom of the daily Teleseismic Report as of 28 May 1976. As event confirmations from PDEs are received studies will be performed to see how many of these event detections are confirmed. If these other detections prove to be legitimate, more time will be spent trying to get a location or a good time to add to our Teleseismic Event Report.

4. Event Processing

The on-line playout program (APPLE) was used to aid the analyst in the processing of events too small to pick delay times from Develocorder film. The APPLE program plays out subarray sum event data from magnetic tape onto a chart record in three passes: first, using raw data; second, through a filter; and last, forming a beam. Further, a cross correlation routine assists with the picking of delays.

All delay times from either the film or the APPLE program are used with the MANBUL program to obtain location and other event parameter information.

C. ARRAY OPERATIONS

1. Monitoring

The array and data center systems are monitored on a continuous basis to provide an up-to-date site/sensor status information input to the LASAPS processor and to alert maintenance to trouble sources. Interruptions of the array data are shown in the monthly operations summary reports. SP data was interrupted 415.0 hr during this period; LP, 323.6 hr. Each SP subarray averaged 3.5 hr/month outage; LP, 4.0 hr/month. Table I indicates the data interruptions by the purpose of the outage and Table II shows a summary by subarray of the outages.

2. Communications Monitoring

Monitoring of the array communications circuits between each of the thirteen subarrays and the data center indicated about the same level of performance as previously observed. The long term circuit availability (since DEC 1970)

TABLE I

DATA INTERRUPTIONS BY PURPOSE OF OUTAGE

JANUARY 1976 - SEPTEMBER 1976

SP ARRAY, 13 SITES	TOTAL HOURS OUT	AVERAGE PER SITE
LDC TESTING	39.536	3.041
SITE FAILURES	64.700	4.977
ON-SITE MAINTENANCE	19.332	1.487
POWER OUTAGE	32.750	2.519
TELCO TEST/OUTAGE	258.637	19.895
TOTAL SP ARRAY	414.955	31.920
LP ARRAY, 9 SITES		
LDC TESTING	30.732	3.415
SITE FAILURES	51.700	5.744
ON-SITE MAINTENANCE	18.882	2.098
POWER OUTAGE	32.750	3.639
TELCO TEST/OUTAGE	193.454	21.495
TOTAL LP ARRAY	323.576	35.953

TABLE II

SUMMARY SUBARRAY DATA INTERRUPTION OUTAGES

JANUARY 1976 - SEPTEMBER 1976

SITE	SP DATA	LP DATA	TELCO OUTAGES
A0	22.574	22.497	34.733
B1	3.041	---	3.183
B2	6.391	---	12.234
B3	2.187	---	6.800
B4	3.158	---	42.916
C1	7.340	7.713	3.350
C2	5.807	6.180	27.016
C3	11.758	12.131	49.734
C4	33.924	24.547	3.234
D1	6.841	7.120	18.644
D2	37.641	38.014	36.835
D3	16.557	16.930	32.584
D4	5.841	6.214	5.634
TOTAL, HRS	163.060	141.346	283.057

of array circuits did not change from 0.99687. Circuit outages - those which normally exceed 2 or 3 minutes - of each subarray are shown together with the short-and long-term circuit availabilities in Table III.

The extended outages exceeding a two-hour duration are listed in Table IV. Approximately 52% of these outages resulted from either lightning or man-caused incidents.

3. Array Calibrations

Sinusoidal claibrations are performed daily using Program TESP for the SP seismographs to determine the condition of the array equipment. LP seismographs are routinely tested each week using Program TELP for sinusoidal calibrations, Program FREEK for free period measurement, and Program MASPOS for measuring and positioning the LP seismometer masses. Other computer controlled tests are periodically performed.

D. ANALOG SYSTEM

Throughout this reporting period the two LASA Short Period Develocorders operated on-line with the array. By using two units and alternating them daily one is always in operation even during film changes and one is ready for recording in case of a malfunction in the operating unit. The recording format consisted of center holes from the C-and D-Ring and AO subarrays except D2 which uses the analog summation signal plus the attenuated signal from AO.

Develocorder film recordings dating from 24 DEC 73 are stored in the library.

TABLE III

ARRAY COMMUNICATIONS OUTAGE STATISTICS

SITE-CIRCUIT	OUTAGE 1/76-9/76 (HOURS)	CIRCUIT AVAILABILITIES SHORT TERM 1/76-9/76	LONG TERM 12/70-9/76
A0 - 4GD2704	34.733	0.99404	0.99508
B1 - 4GD2701	3.183	0.99945	0.99834
B2 - 4DG2710	12.284	0.99789	0.99766
B3 - 4GD2705	6.800	0.99883	0.99816
B4 - 4GD2707	42.916	0.99264	0.99723
C1 - 4GD2708	3.350	0.99942	0.99844
C2 - 4GD2709	27.016	0.99537	0.99666
C3 - 4GD2711	49.734	0.99147	0.99356
C4 - 4GD2706	3.234	0.99946	0.99733
D1 - 4GD2714	18.634	0.99818	0.99661
D2 - 4GD2715	35.485	0.99382	0.99843
D3 - 4GD2712	32.536	0.99442	0.99872
D4 - 4GD2713	5.634	0.99903	0.99886
ALL SITES	28.580(AVE) 267.539(TOTAL)	0.99647	0.99814

TABLE IV

EXTENDED ARRAY DATA INTERRUPTIONS DUE TO COMMUNICATIONS OUTAGES

JANUARY - SEPTEMBER 1976

DATE	DURATION (HR:M)	SITE	REASON FOR OUTAGE
MAR 05	8:08	C2	NO TROUBLE FOUND - CAME CLEAR
MAY 05	6:31	C2	BILLINGS TOLL TEST PROBLEM
MAY 25	4:24	D1	BILLINGS TOLL TEST PROBLEM
MAY 25	4:24	B2	BILLINGS TOLL TEST PROBLEM
MAY 25	4:24	C2	BILLINGS TOLL TEST PROBLEM
JUN 07	16:38	D2	562A FILTER BAD
JUN 07	9:21	C3	KS AMP BAD
JUN 12	18:15	B4	LIGHTNING CAUSED OPEN WIRE PROBLEM
JUN 13	16:50	B4	DATA SET BAD
JUN 22	2:44	B4	LIGHTNING COUSED OPEN WIRE PROBLEM
JUL 19	18:35	A0	MODEM BAD - LIGHTNING CAUSED
JUL 25	4:35	A0	MODEM FAILURE
JUL 29	23:57	D3	OPEN WIRE LINE SEVERED BY FARMER
JUL 29	30:51	C3	OPEN WIRE LINE SEVERED BY FARMER
JUL 29	4:23	A0	MODEM TROUBLE
JUL 30	2:18	D3	RELEASE TO REPLACE SEVERED POWER LINES
AUG 03	3:30	B3	OPEN WIRE LINE SEVERED BY FARMER
SEP 09	2:10	B2	RADIO FAILED ANGELA
SEP 09	2:10	C2	RADIO FAILED ANGELA
SEP 09	2:10	C3	RADIO FAILED ANGELA
SEP 09	2:10	D1	RADIO FAILED ANGELA
SEP 09	2:10	D3	RADIO FAILED ANGELA
SEP 09	2:10	D4	RADIO FAILED ANGELA

E. DATA LIBRARY

Recording of the arrays seismic data at the LDC covered 6353.3 hrs or 96.61% of the past nine-months. These 9460 recordings were recycled through the LDC's Data Library so that each recording was retained for at least 60 days before reuse.

The LASA Data Library contains the following tapes

LIARS Backup Recording Cycle	2101 Tapes
LDC Permanent Tapes	547 Tapes
AUTO-EDIT Master Tapes	45 Tapes
Calibration Periods	99 Tapes

Six shipments totalling 47 tapes were made to SDAC during this reporting period.

D. Gress and R. Matkins

SECTION III

ARRAY PERFORMANCE

The performance of the array as determined locally is based on the results of our seismic event processing, SP and LP seismometer testing and reliability studies. Results from each of these activities are summarized in the following paragraphs.

A. Seismic Event Processing

1. Teleseismic Processing Results

Following the teleseismic processing procedure described in Reference 1, we have reported to VSC 2897 events and 508 phases between January 1 through September 30, 1976. These events are classified in Table V and show an average of 19.4 detections reported per day. Approximate locations have been indicated for 60% of the detected events. Figures 3.1 and 3.2 show distributions of the detections by event classification and the percentage located each month.

Magnitudes were determined for 1688 of the located events. The smallest magnitude reported was 3.4; the largest 7.3. Figure 3.3 shows the distribution of these event magnitudes. The distribution of all 2883 event magnitudes reported since this effort began on June 16, 1975 is shown in Figure 3.4.

2. Near-regional Detections

The LASA near-regional detection reports which indicate a portion of the near-regional activity and identify interferring signals continued with 32 reports issued between January 1 and September 30, 1976. A total of 169 near-regional

TABLE V

Classification of Detected Teleseismic Events

June 16 - December 31, 1975

Event Classification	Number of Events	Daily Average
Located teleseisms (excluding PKP's)	1692	6.18
PDP (located)	55	0.20
PDP (unlocated)	286	1.04
Poor or weak teleseisms (not located)	864	3.15
pP Phases	277	1.01
Other Phases	231	0.84
Unprocessed detections (since May 28, 1976)	977	6.96
Total	4282	19.38

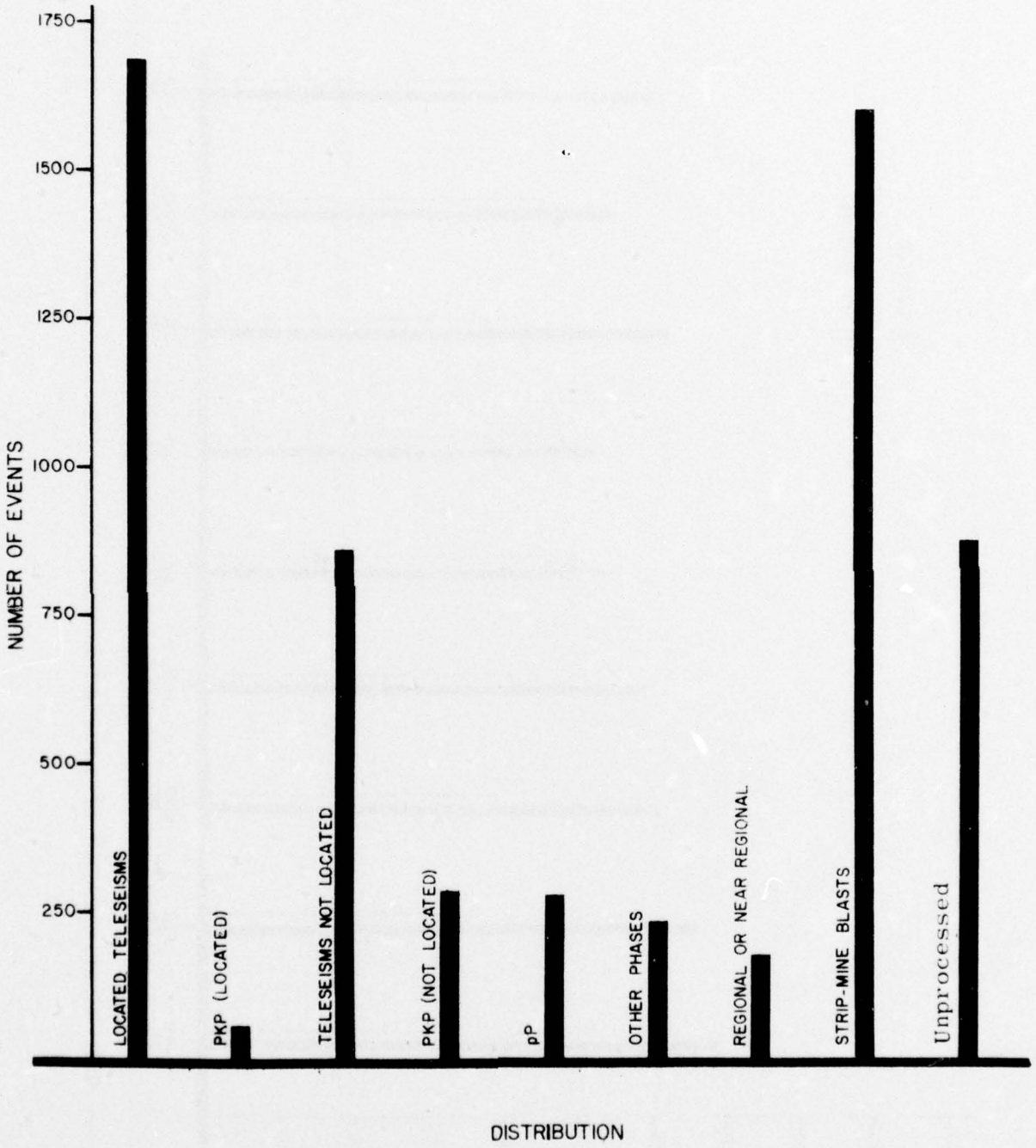

Figure 3.1 Distribution of Detected Events, January-September, 1976

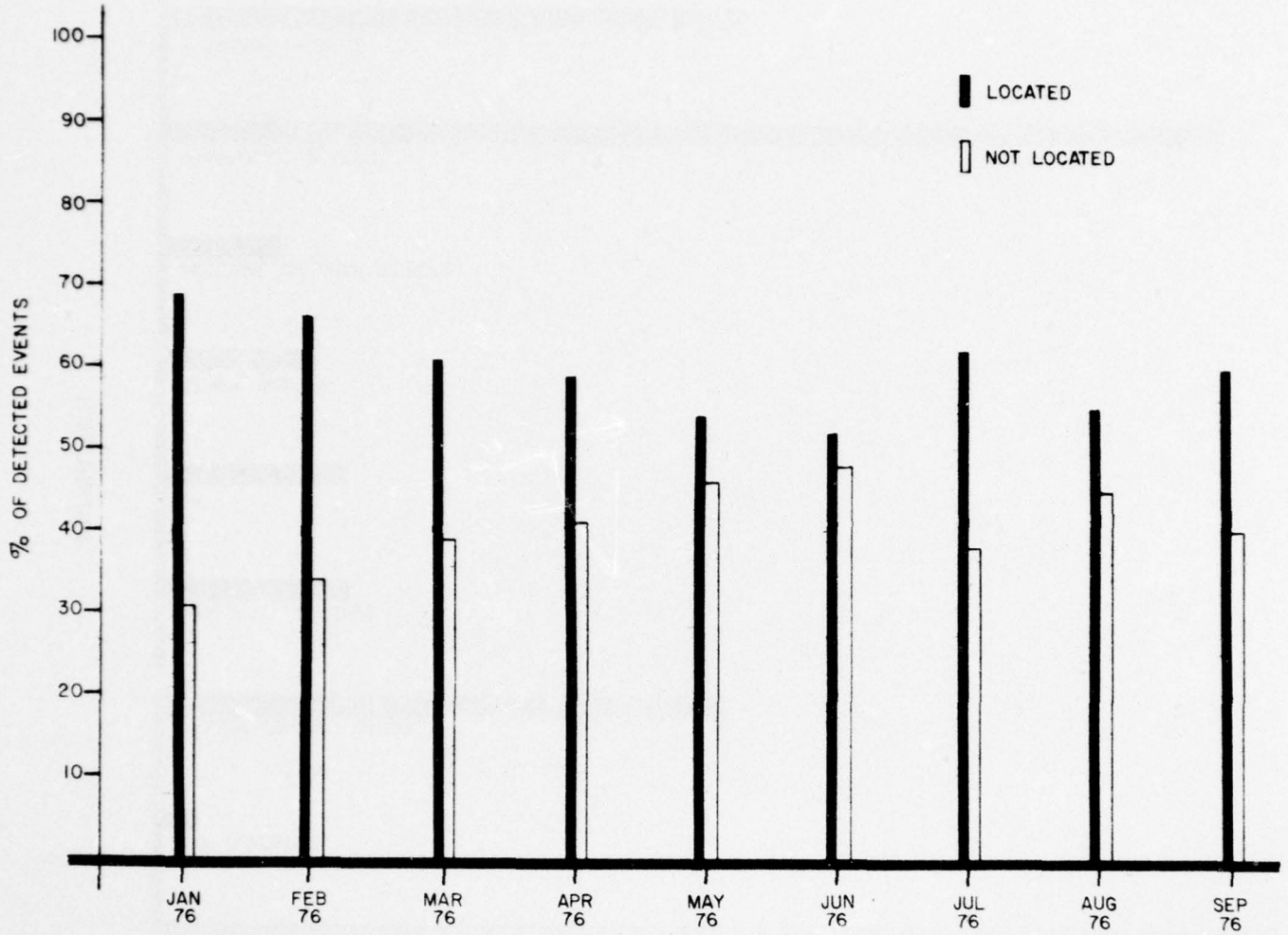

Figure 3.2 Distribution of Located and Not-located Teleseismic Events by Month

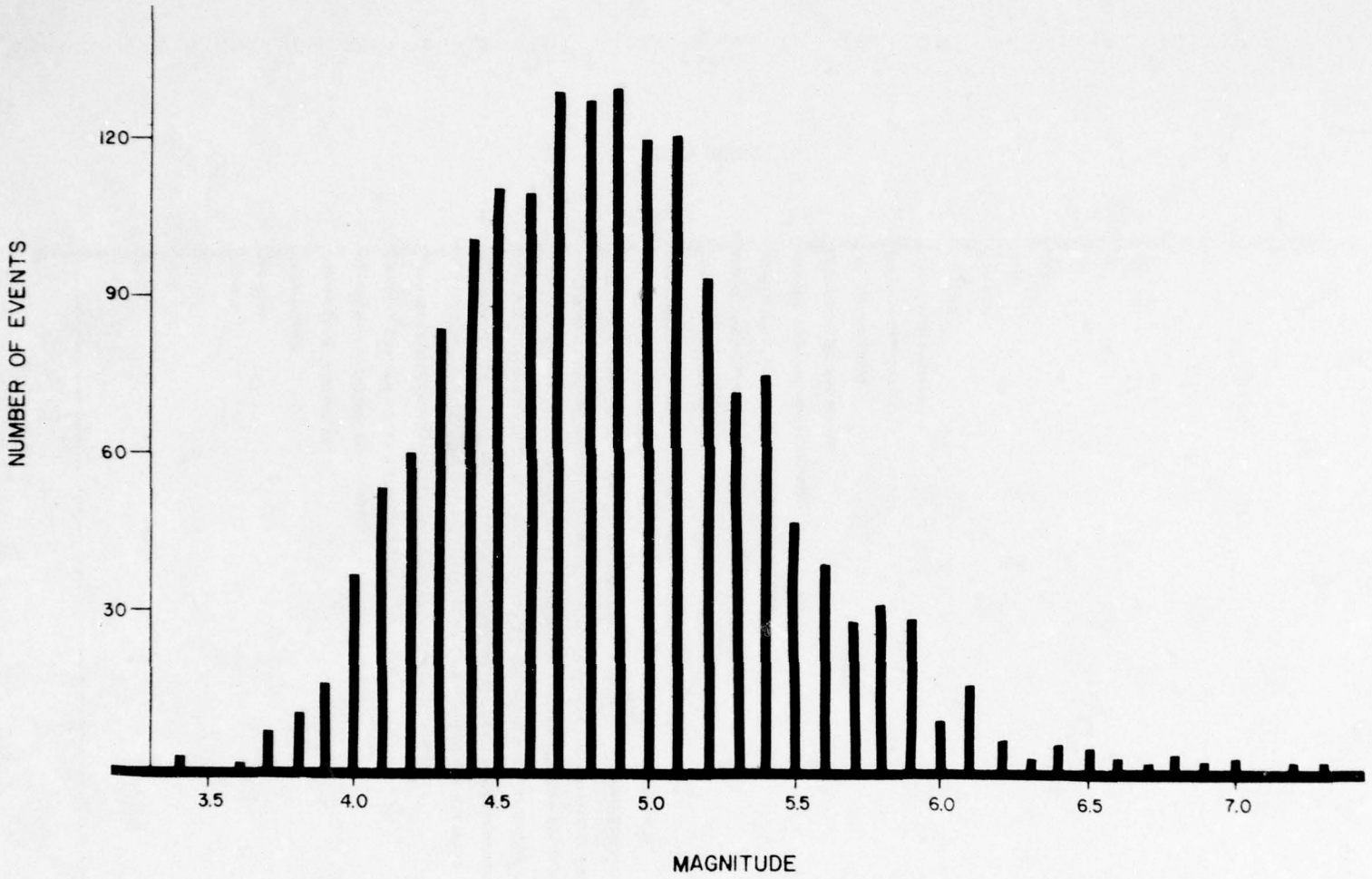

Figure 3.3 Magnitude Distribution of Located Events, January-September, 1976

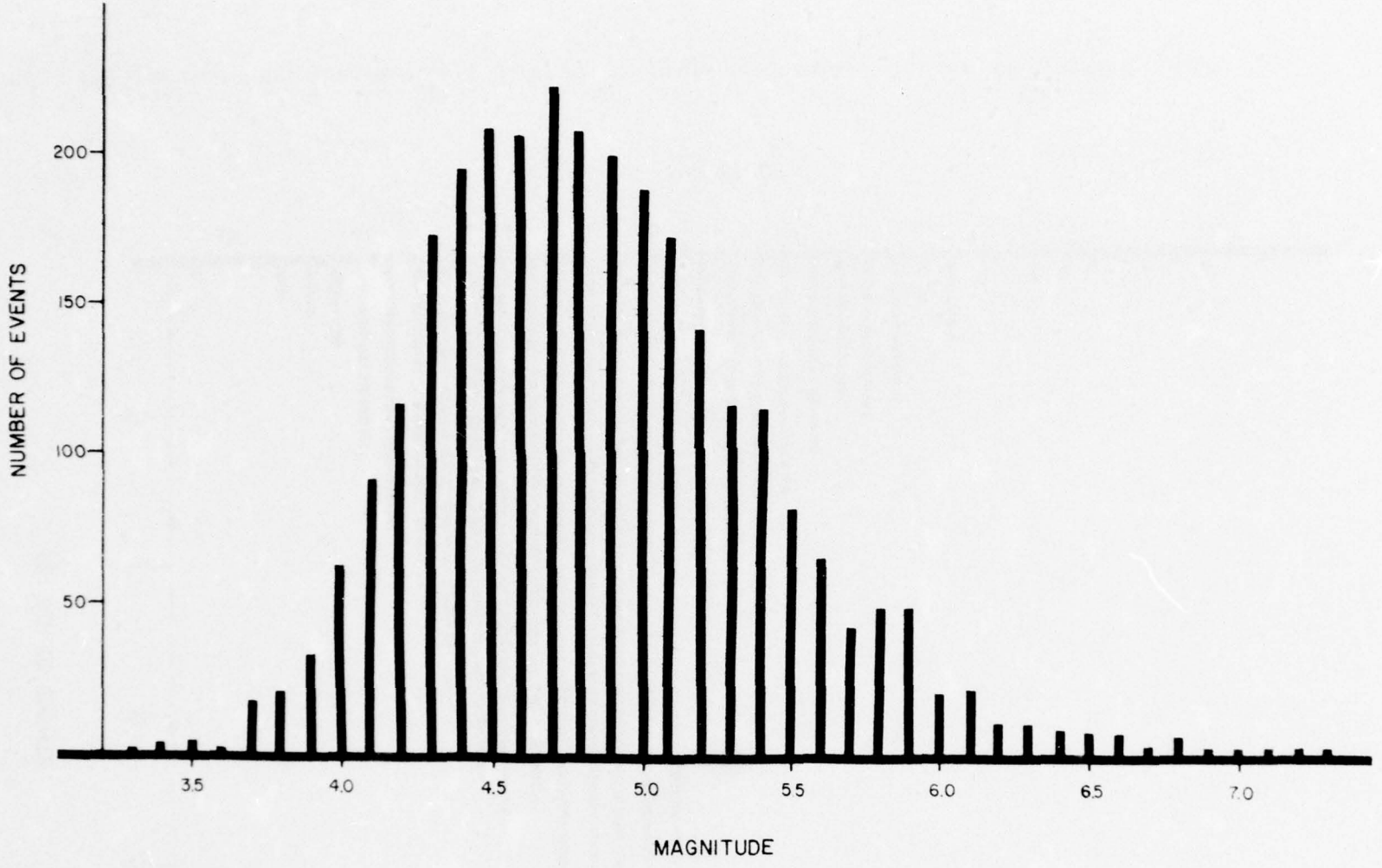

Figure 3.4 Magnitude Distribution of Located Events, June 16, 1976-Sept. 30, 1976

or regional arrivals were covered. Unidentified events account for the majority of the arrivals. Locations were estimated for 23 events.

Periodic supplements report the blasting activity at the known strip mines located near the LASA. Table VI shows the number of blasts detected from each of the several strip mines in the region. The blasting activity during this nine-month period increased by about 12% to an average of 5.8 blasts/day from 5.2 reported for the previous period.

3. Comparison with NEIS Reports

The LASA data center teleseismic reports are compared with the Preliminary Determination of Epicenter (PDE) reports received from NEIS as time permits. Between June 16, 1975 and June 9, 1976, the LDC reports covered 1836 of the 3910 events listed in the PDEs (1975 thru 46-75 and 1976 thru 08-76) or 47.0%.

Comparison of the magnitudes calculated at the LDC with those listed in the PDE's results in the distribution shown in Figure 3.5. The LDC determined magnitudes averaged 0.04 Richter units greater than those reported in the PDEs for a population of 1270 events. Since the PDE values are themselves averages, the comparison shown here is indictive of the quality of the LASA estimates but does not allow making any corrections or modifications to the local method of determining event magnitude.

Comparison of a limited number of event locations has been made between the LDC reports and the PDEs. Using 550 events, the first to be reported in the PDEs during the period

TABLE VI

Summary of Strip-mine Blasting Activities Reported by LDC

January 1 - September 30, 1976

Location	Number Blasts Reported	
Colstrip, MT (WE)	574	(35.9%)
Decker, MT	326	(20.4%)
Sarpy Creek, MT (W)	194	(12.1%)
Colstrip, MT (P)	181	(11.3%)
Wyoming	112	(7.0%)
British Columbia, Canada	107	(6.7%)
Unknown, NE	74	(4.6%)
Unknown	12	(0.8%)
South Dakota	9	(0.6%)
Seismic Crew in Array, Series of Shots	6	(0.4%)
Roundup, MT	2	(0.1%)
Warren, MT	1	(0.1%)
TOTAL	1598	(100.0%)

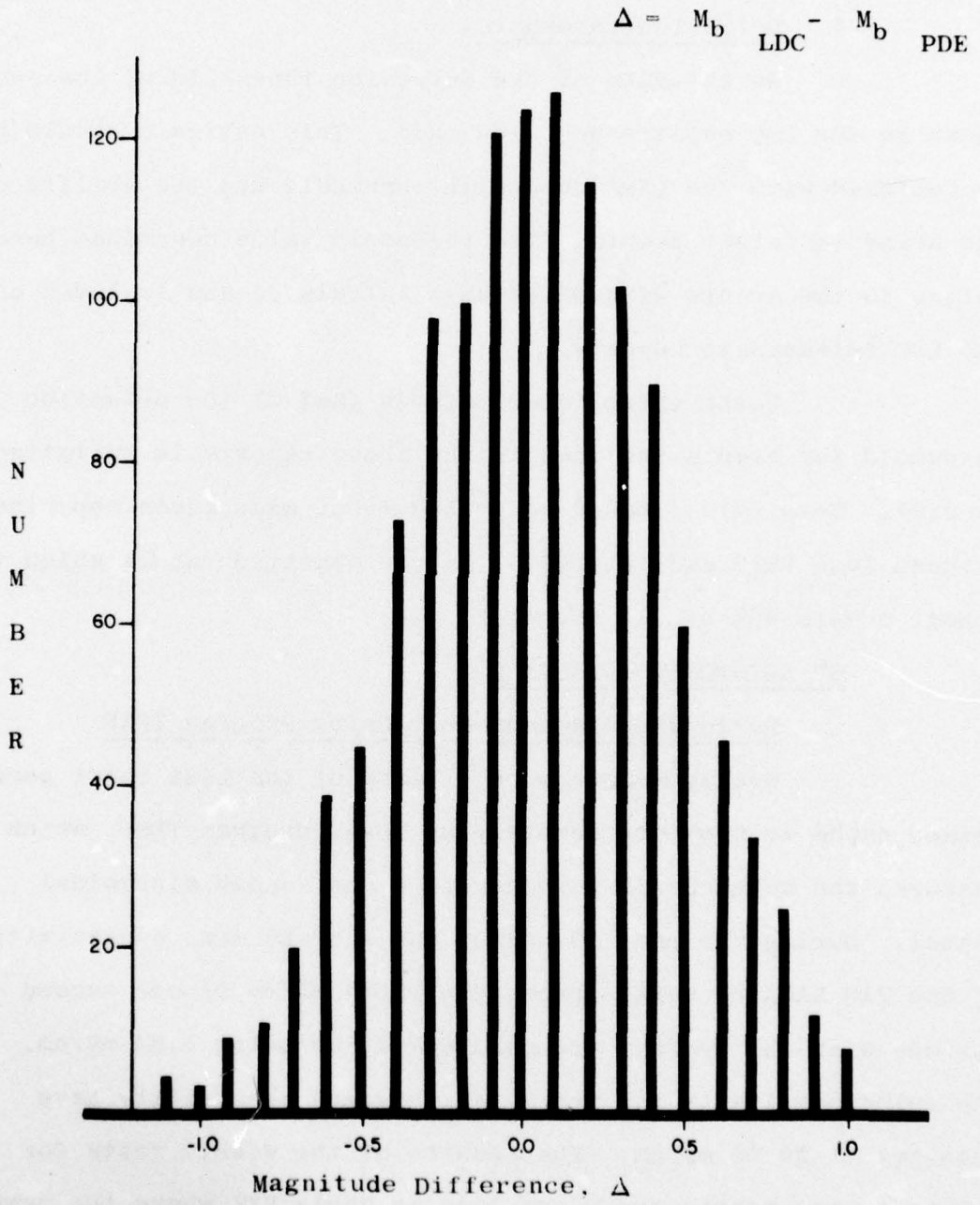

Figure 3.5 Magnitude Difference Between LASA and PDE Calculations

June 75 and Jan 76, which had been located from P-wave arrivals, the location differences averaged 5.8 degrees (σ, 0.51 deg).

4. Detection Threshold

An estimate of the detection threshold of the events shown in the LDC reports has been made. This estimate should not be confused with the LASA detection threshold and the ability of the array to detect events. The threshold value described here refers to the events with magnitudes calculated and included on the LDC teleseismic reports.

Using established methods (Ref 2) the detection threshold for events included in the above reports is estimated at 4.97. This value, based upon 2560 event magnitudes reported between June 1975 and July 1976, is the magnitude above which the report covers 90% of all events.

B. SP SEISMOMETER TESTING

1. Performance Measurement Using Program TESP

Weekly measurement of each of the LASA short period seismographs is provided remotely by PDP-7 program TESP, which measures the seismograph response to a one second sinusoidal signal. During the past 15 months the average mean sensitivity of the 210 LASA SP seismographs was 19.83 mV/nm at one second periods with the average standard deviation being 0.83 mV/nm. The tolerance limits for the SP seismograph sensivitity have been set at 20 ±3 mV/nm. The results of the weekly tests for the past nine months are summarized in Table VII where the number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity

TABLE VII

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO SENSORS	SENS MEAN MV/NM	SENS MV/NM	SENS MAX MV/NM	SENS MIN MV/NM	SENS DEV MV/NM
01/05	207	19.83	0.58	22.71	17.31	5.40
01/12	207	19.87	0.65	23.32	12.48	10.84
01/19	208	19.89	0.68	23.10	12.70	10.40
01/26	197	19.84	0.80	23.07	17.87	5.20
02/02	208	19.98	0.58	21.79	17.60	4.19
02/09	161	19.90	0.77	24.08	17.62	6.38
02/16	208	19.94	0.56	21.46	17.79	3.67
02/23	208	19.93	0.62	21.51	16.71	4.80
03/01	208	19.91	0.73	22.24	14.60	7.64
03/08	200	19.94	0.69	21.51	14.93	6.58
03/15	208	19.90	0.64	21.86	16.48	5.38
03/22	208	19.98	0.54	21.33	17.60	3.73
03/30	208	19.92	0.54	21.24	17.65	3.59
04/05	200	19.95	0.62	21.72	17.46	4.20
04/12	207	19.63	0.85	23.03	16.73	6.38
04/19	208	19.96	0.61	21.61	17.36	4.25
04/26	200	19.89	0.69	22.57	17.67	4.98
05/03	208	19.92	0.60	22.15	17.83	4.32
05/10	208	19.56	0.88	22.86	16.52	6.34
05/17	206	19.46	0.95	23.03	16.42	7.41
05/24	208	19.56	0.81	23.20	16.70	6.50
05/31	208	19.54	0.80	22.13	16.75	5.38
06/08	207	19.20	0.93	22.18	16.10	6.88
06/14	208	19.66	0.79	22.11	17.77	4.34
06/28	207	19.60	0.95	24.52	17.02	7.50
07/05	207	19.25	0.94	22.88	13.92	8.16
07/13	208	18.97	1.07	23.26	16.44	6.82
07/19	207	19.12	1.01	22.71	16.89	5.82
07/26	208	18.71	1.20	23.22	16.10	7.12
08/02	207	19.23	1.09	22.91	16.77	6.14
08/09	208	19.36	1.08	22.40	16.86	5.54
08/23	209	18.81	1.18	23.13	15.74	7.39
08/30	200	19.73	0.95	22.37	17.65	4.72
09/06	207	19.79	0.99	22.86	17.73	5.13
09/20	209	20.50	0.93	24.07	18.14	5.93
AVERAGE	206	19.67	0.82	22.57	16.63	5.95
CONTRACT AVERAGE	197	19.83	0.97	23.31	18.69	6.22
PREVIOUS CONTRACT AVERAGE	206	20.05	0.85	23.36	16.78	6.58

for the array, and the difference between the maximum and minimum sensitivity are given by week.

Sensitivity is a function of the output of the seismometer divided by the input to the seismometer and is calculated using the following relationship:

$$S = \left(\frac{4\pi^2 M}{G_C T^2}\right)\frac{E_o}{I} = 1.01 \times 10^3 \frac{E_o}{I} \text{ volts/meter}$$

where S = SP Channel Sensitivity at period T
M = SP Seismometer moving mass
E_o = SP Channel Output Voltage
G_C = SP Seismometer generator constant
I = Calibration current in amps into the SP seismometer Calibration Coil.

2. Seismometer Natural Frequency & Damping Measurements

The SP seismometer natural frequency and damping field measurements completed this period have only slightly revised the distributions of these two parameters. Histograms of the natural frequency and damping measurements are shown in Figures 3.6 and 3.7, repsectively. The two sensors with a damping ratio of .643 were surface (10 ft. deep) installations at subarray D1. The measurements were made during a windy day causing the instruments to be very noisy so the ratio may not be correct.

3. SP Sensor Replacements

A brief analysis of the replacements and repairs of the SP sensor equipment shows 21 different WHV maintenance actions: two seismometers, 16 amplifiers and three wellhead vaults. One seismometer was tested to measure the damping ratio and one was replaced because of low output. Three wellhead vaults were dried out and sealed to correct leaks. The 16 RA-5 amplifier

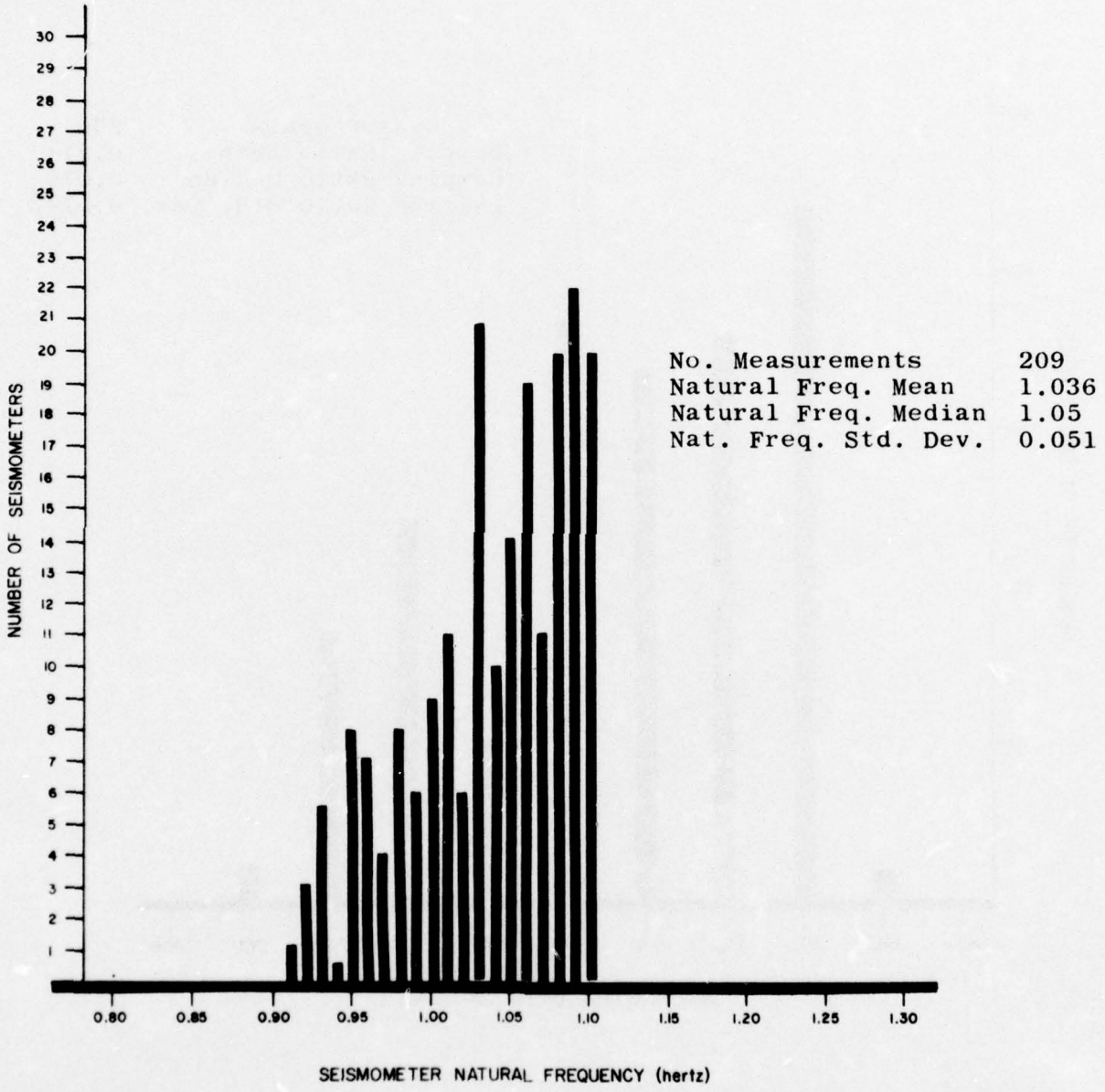

Figure 3.6 SP Seismometer Natural Frequency Distribution, September 1976

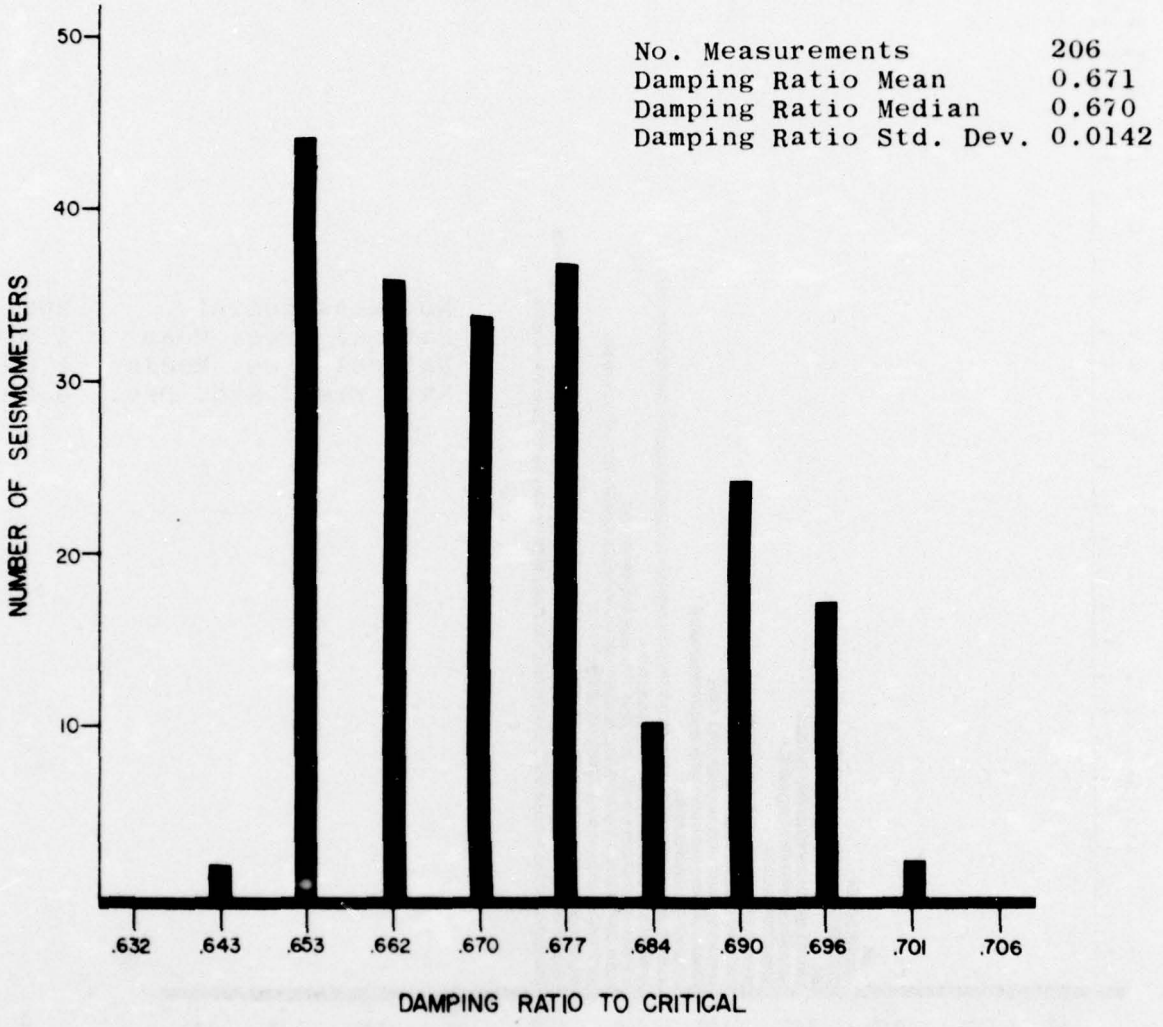

Figure 3.7 SP Seismometer Damping Ratio Distribution, September 1976

TABLE VIII

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

DATE	NO SENSORS	SENS MEAN MV/μM	SENS MV/μM	SENS MAX MV/μM	SENS MIN MV/μM	SENS DEV MV/μM
01/19	22	356.3	24.5	401.8	294.1	106.9
01/26	24	356.8	21.3	397.7	294.1	103.6
02/02	24	358.7	23.7	425.3	293.0	132.3
02/09	24	353.9	26.1	425.3	289.7	135.6
02/16	23	351.8	18.6	378.3	283.2	95.1
02/23	24	351.2	18.3	376.2	283.2	93.0
03/08	24	348.9	28.5	397.8	278.1	119.7
03/15	24	352.9	11.7	376.2	332.4	43.8
04/26	24	344.6	16.5	368.9	291.3	77.6
05/03	24	342.6	17.3	369.9	285.8	84.1
05/10	24	342.3	11.6	367.6	328.6	43.8
05/17	24	340.9	11.6	364.4	318.4	46.0
05/24	24	336.5	14.4	361.2	304.5	56.7
05/31	24	335.8	20.8	378.8	275.9	102.1
06/08	24	332.8	21.8	381.9	270.4	111.5
06/14	24	336.3	23.8	400.4	271.5	128.9
06/28	24	336.9	20.2	400.4	305.6	94.8
07/05	23	329.8	20.4	397.8	283.2	114.6
07/13	24	330.8	20.2	361.5	285.8	75.7
07/26	24	326.8	25.3	361.6	238.6	123.0
08/02	24	337.1	24.6	404.9	266.0	138.9
08/23	24	338.4	19.9	402.1	304.0	98.1
08/30	24	339.1	22.2	417.8	307.5	110.3
09/06	24	337.6	22.1	413.4	304.6	109.4
09/13	24	339.6	22.1	413.4	307.1	106.3
09/20	24	340.9	22.7	416.5	305.4	111.1
AVERAGE	23.9	342.3	20.1	390.6	292.1	98.5
CONTRACT AVERAGE	24.9	339.9	19.2	383.9	284.9	89.0
PREVIOUS CONTRACT AVERAGE	26	337.4	18.2	376.7	287.9	78.8

replacements corrected seven inoperative channels, six distorted outputs, and three erratic and unstable outputs.

C. LP SEISMOMETER TESTING

1. Performance Measurement Using Program TELP

Program TELP measures the response of the LASA long period seismographs to a 25-second sinusoidal signal. A summary of the weekly tests for the 15-month contract using program TELP show an average mean sensitivity of 339.9 mV/μm. The tolerance limits for the 27 long period seismographs have been established at 350 ±50 mV/μm. Table VIII is a summary, by week, of the tests for the past 9 months. Included in the summary are the number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity for the array, and the difference between the maximum and minimum sensitivity.

Sensitivity, a function of seismograph output divided by the input, is calculated according to the following relationship.

$$S = \left(\frac{4\pi^2 M}{G_C T^2}\right)\frac{E_o}{I} = 22.56\,\frac{E_o}{I} \quad \text{volts/meter}$$

where S = LP Channel Sensitivity at period T
M = LP Seismometer moving mass
E_o = LP Channel output voltage
G_C = LP Seismometer generator constant
I = Calibration current in amps into the LP Seismometer Calibration Coil.

2. Results of MASPOS and FREECK

The free period of the array's 24 LP seismometers averaged 20.02 seconds (σ, 0.10s) over the 38 weeks of this reporting period. Remote adjustments to maintain the free period to a 20.0 ± 1.0 seconds totalled 54 for an average of 1.4 per test.

TABLE IX

LP SEISMOMETER REMOTE ADJUSTMENTS

	MASS POSITION ADJUSTS		AVE	FREE PERIOD ADJUSTS		AVE	COMBINED ADJUSTMENTS		AVE
	01/76 TO 10/76	12/71 TO 10/76	DAYS-BETWEEN ADJUSTS	01/76 TO 10/76	01/73 TO 10/76	DAYS-BETWEEN ADJUSTS	01/76 TO 10/76	LONG TERM	DAYS BETWEEN ADJUSTS
A0 V	4	39	45.21	7	10	136.60	11	49	31.93
A0 NS	4	30	58.77	7	16	85.38	11	46	34.01
A0 EW	8	53	33.26	2	7	195.14	10	60	26.08
C1 V	4	40	44.08	1	13	105.08	5	53	29.52
C1 NS	5	36	48.57	3	17	80.35	8	53	29.52
C1 EW	4	41	43.00	3	11	124.18	7	52	30.09
C2 V	9	48	36.73	2	12	113.83	11	60	26.08
C2 NS	14	55	32.85	7	32	42.69	21	87	17.98
C2 EW	13	78	22.00	3	13	105.08	16	91	17.19
C3 V	9	63	27.98	0	3	455.33	9	66	23.70
C3 NS	10	65	27.12	1	9	151.78	11	74	21.14
C3 EW	9	71	24.83	1	8	170.75	10	79	19.80
C4 V	6	49	35.98	1	4	341.50	7	53	29.52
C4 NS	1	22	80.14	1	4	341.50	2	26	60.17
C4 EW	6	54	32.65	1	2	683.00	7	56	27.93
D1 V	5	38	46.39	0	7	195.14	5	45	34.77
D1 NS	28	100	17.63	3	18	75.89	31	118	13.26
D1 EW	33	92	19.16	4	12	113.83	37	104	15.04
D2 V	6	50	35.26	0	7	195.14	6	57	27.45
D2 NS	4	46	38.33	0	2	683.000	4	46	34.01
D2 EW	8	72	24.49	0	2	683.00	8	72	21.73
D3 V	8	66	26.71	1	5	273.20	9	71	22.04
D3 NS	2	25	78.52	0	4	341.50	2	29	53.05
D3 EW	1	14	125.93	1	3	455.33	2	17	92.83
D4 V	6	50	35.26	0	3	455.33	6	53	29.52
D4 NS	16	116	15.20	5	23	59.39	21	139	11.26
D4 EW	6	44	40.87	0	10	136.60	6	54	28.97

The extent of the frequency variation is shown by the average of the standard deviations of the each week's test data. Prior to the remote adjustments the average standard deviation was 0.65 sec and immediately after 0.52 sec.

Mass position centering to within ±1.40 mm required 229 remote adjustments, an average of 6.1 per test.

3. LP Seismometer Positioning Analysis

The long term positioning statistics for the LP seismometers are shown in Table IX where the remote adjustments for both mass positioning (since 6 DEC 71) and free period correction (since 2 JAN 73) are shown and total 1710. The mean-time-between-adjustment (MTBA) for each seismometer is shown and varies from 11.26 days for sensor D4 N/S to 92.03 days for sensor D3 E/W. The average MTBA for the array is 0.91 days and for a seismometer is 24.70 days.

D. RELIABILITY

The reliability of the Montana array systems is described in terms of equipment failure rates, mean-time-between-failures (MTBF), and system availability figures.

1. Failures

Failures, defined as a condition which requires the replacement of a faulty component to repair, are declared at the time the maintenance work order is completed and the failed component has been identified. Conditions which can be corrected by adjustment or replacement of such items as batteries and lamps are considered as troubles but not failures.

The long term failure rates and MTBF history of the

LASA equipment are shown in Table X. Data used in these statistics cover the periods beginning March 1970 and July 1973 and extending through September 1976. With the exception of the two computer systems and the analog system, the MTBF increased for all systems from the intervals shown in our first semi-annual report. The PDP-7 computer had a 7.9% increase in MTBF; the Analog system, 1.8% and the 360 computer system, 0.5%.

2. Systems Availability

System availabilities are calculated for the six primary systems or groups as an aid in evaluating the LASA operational performance. The availability or uptime factors are shown in Table XI. Using these figures, the fifteen month availability averages for the three major system configurations are:

LASAPS/SP Array	0.95280
LASAPS/LP Array	0.94726
LASAPS/Backup Recording	0.97484

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and T. Smith

TABLE X

EQUIPMENT FAILURE RATES

ARRAY SYSTEM/EQUIPMENT	FAILURES/HOUR SINCE 03/70	FAILURES/HOUR SINCE 03/73	MTBF SINCE 07/70	MTBF SINCE 07/73
SHORT PERIOD SYSTEM	0.00843	0.00540	119	185
SEISMOMETER	0.00166	0.00130	602	771
UHV AMPLIFIER	0.00653	0.00389	153	287
POWER SUPPLY	0.00019	0.00018	5249	5702
UHV CIRCUITS	0.00000	0.00000	--	--
UHV CABLING	0.00002	0.00004	57774	28512
CTH CIRCUITS	0.00003	0.00000	28872	--
LONG PERIOD SYSTEM	0.00043	0.00049	2310	2037
VERT. SEISMOMETER/TANK	0.00002	0.00004	57774	28512
HORZ. SEISMOMETER/TANK	0.00003	0.00007	28872	14256
LP VAULT CABLING	0.00000	0.00000	--	--
LP JUNCTION ASSEMBLY	0.00003	0.00007	28872	14256
LP VAULT TERMINAL	0.00000	0.00000	--	--
MOTOR ASSEMBLY	0.00002	0.00000	57774	--
SEISMIC AMPLIFIER	0.00029	0.00032	3397	3160
POWER SUPPLY	0.00002	0.00000	57774	--
CTH CIRCUITS	0.00002	0.00000	57774	--
SUBARRAY ELECTRONICS MODULES	0.00242	0.00144	410	695
INPUT DRAWERS	0.00055	0.00032	1804	3168
MULTIPLEXER ADC	0.00024	0.00039	4125	2592
OUTPUT DRAWER	0.00023	0.00011	4442	9504
CONTROL DRAWER	0.00133	0.00063	750	1584
AUXILARY CONDITIONING	0.00005	0.00000	19248	--
SEM CABINET/CABLING	0.00002	0.00000	57744	--
ALARMS	0.00002	0.00000	57744	--
SUBARRAY POWER SYSTEM	0.00031	0.00021	3288	4752
CONTROL ASSEMBLY	0.00012	0.00007	8249	14256
INVERTER	0.00014	0.00014	7218	7128
CHARGER	0.00002	0.00000	57744	--
BATTERY	0.00000	0.00000	--	--
SOLA TRANSFORMER	0.00002	0.00000	57744	--
RACK/CABLING	0.00002	0.00000	57744	--
ISOLATION TRANSFORMER	0.00000	0.00000	--	--
CTH WIRING/BREAKERS	0.00000	0.00000	--	--
360 COMPUTER	0.00080	0.00116	1255	864
CPU 2844	0.00028	0.00042	3609	2376
DISC DRIVE 2315	0.00003	0.00004	28872	28512
TYPEWRITER 1052	0.00043	0.00063	2310	1584
CARD READER 2501	0.00000	0.00000	--	--
DATA CONTROL 1826	0.00002	0.00004	57774	28512
DATA ADAPTER 1827	0.00003	0.00004	28872	28512
DATA ADAPTER 2701	0.00002	0.00000	57774	--

TABLE X (CONCLUDED)

EQUIPMENT FAILURE RATES

ARRAY SYSTEM/EQUIPMENT	FAILURES/HOUR SINCE 03/70	FAILURES/HOUR SINCE 03/73	MTBF SINCE 0?/70	MTBF SINCE 07/73
PDP-7 COMPUTER	0.00071	0.00077	1408	1296
CPU	0.00043	0.00049	2310	2037
TELEPRINTER KSR-35	0.00019	0.00018	5249	5702
CARD READER	0.00009	0.00011	11549	9504
SERIAL OUTPUT UNIT	0.00000	0.00000	--	--
DIGITAL SYSTEM	0.00014	0.00021	7218	4752
TIMING SYSTEM	0.00009	0.00014	11548	7128
POWER SYSTEM	0.00002	0.00004	57744	28512
PLINS	0.00000	0.00000	--	--
MINS	0.00003	0.00004	28872	28512
ANALOG SYSTEM	0.00097	0.00140	1031	713
DA CONVERTERS	0.00017	0.00021	5774	4752
FM SYSTEM	0.00002	0.00000	57744	--
WWV RECIEVER	0.00002	0.00000	57744	--
ANALOG CALIBRATION SYSTEM	0.00000	0.00000	--	--
ANALOG TIMING SYSTEM	0.00002	0.00004	57744	28512
DEVELECORDERS	0.00064	0.00105	1561	950
16 CHANNEL CHART RECORDER	0.00009	0.00007	11548	14256
LDC TEST AND SUPPORT	0.00061	0.00063	1650	1584
MAINT. DISPLAY CONSOLE	0.00038	0.00028	2625	3564
FILM VIEWER	0.00000	0.00000	--	--
TAPE CLEANER	0.00003	0.00000	28872	--
DIGITAL CLOCKS	0.00000	0.00000	--	--
EMERGENCY LIGHTS	0.00000	0.00000	--	--
BLOWER, COMPRESSOR	0.00002	0.00004	57744	28512
AIR CONDITIONER	0.00014	0.00025	7218	4073
HUMIDIFIER	0.00002	0.00004	57744	28512
ELECTROSTATIC FILTERS	0.00000	0.00000	--	--

TABLE XI

LASA SYSTEM AVAILABILITIES

MONTH	360 COMP	LDC DATA ACQ.	PDP-7 COMP	DATA COMM	SP ARRAY	LP ARRAY	LASAPS SP ARRAY	LASAPS LP ARRAY	LASAPS BACKUP RECORD
JUL 75	0.9899	1.0000	0.9936	0.9962	0.9893	0.9741	0.9756	0.9607	0.9538
AUG 75	0.9798	1.0000	0.9867	0.9963	0.9938	0.9947	0.9702	0.9710	0.9727
SEP 75	1.0000	1.0000	0.9944	0.9993	0.9976	0.9700	0.9968	0.9772	0.9694
OCT 75	1.0000	1.0000	0.9898	0.9962	0.9960	0.9891	0.9922	0.9853	0.9713
NOV 75	1.0000	1.0000	0.9976	0.9981	0.9698	0.9992	0.9679	0.9973	0.9649
DEC 75	0.8594	1.0000	0.9965	1.0000	0.9881	0.9974	0.8492	0.8572	0.9821
JAN 76	1.0000	1.0000	0.9913	0.9997	0.9939	0.9721	0.9936	0.9718	0.9741
FEB 76	0.9928	1.0000	0.9984	0.9999	0.9985	0.9752	0.9912	0.9680	0.9852
MAR 76	0.9946	1.0000	0.9970	0.9990	0.9968	0.9838	0.9905	0.9775	0.9768
APR 76	0.9967	1.0000	0.9883	1.0000	0.9943	0.9752	0.9911	0.9720	0.9733
MAY 76	0.9270	1.0000	0.9961	0.9976	0.9966	0.9902	0.9216	0.9157	0.9872
JUN 76	0.9286	0.9976	0.9928	0.9893	0.9895	0.9941	0.9069	0.9112	0.9742
JUL 76	0.7964	0.9983	0.9956	0.9991	0.9943	0.9834	0.7818	0.7732	0.9737
AUG 76	0.9848	1.0000	0.9927	0.9991	0.9922	0.9949	0.9765	0.9791	0.9857
SEP 76	0.9958	0.9998	0.9959	0.9979	0.9940	0.9988	0.9868	0.9916	0.9783

SECTION IV

IMPROVEMENTS AND MODIFICATIONS

A. PDP-7 PROGRAMMING

The development and maintenance of programs for the PDP-7 computer provide an important part of the overall task of operating and improving the Montana Array as a seismological observatory. Several programs and program changes were necessary to accomplish the requirements of Project VT/6708. These are listed in Table XII.

Programming changes made during this reporting period included: (1) adding the ability to classify events on the edit tapes produced by the AUTO-EDIT program (Ref. 1); (2) putting the LASA material inventory program on-line with such operator features as search and edit, update, and list; (3) outputting a 10-second time tick to the Develocorders by the LIARS program; and (4) updating the seismograph broadband calibration programs (RPGONE and RPGTWO) to operate with LIARS recorded data tapes.

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TABLE XII

PDP-7 PROGRAMMING ACTIVITY

July 75 - September 76

PROGRAM	VERSION	BY	DATE APPROVED
AUTO-EDIT	1	Potter	09/75
APPLE	2	Lidderdale	10/75
AUTO-EDIT	2	Potter	10/75
AUTO-EDIT	3	Potter	11/75
APPLE	3	Lidderdale	03/76
MATERIAL INV	1	Lidderdale	05/76
DIAZ	1	Potter	06/76
TESP	12	Lidderdale	06/76
RPG I	3	Lidderdale	06/76
LIARS	2	Lidderdale	07/76
AUTO-EDIT	4	Potter	08/76
RPG II	5	Lidderdale	08/76
TESP	13	Lidderdale	09/76

SECTION V

MAINTENANCE

LASA maintenance activity is divided into three different categories: Data Center (LDC), Maintenance Center (LMC) and Facilities Support. The LDC in Billings operates and maintains the following five systems: The IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog, and the LDC Test and Support. The LMC located in Miles City maintains all array equipment systems which are comprised of SP Sensor, LP Sensor, Meteorological, SEM, and Power. Facilities Support provides maintenance of buildings, vehicles, land leases, and array facilities such as cable trenches, access trails, fences, WHV sites, and CTH sites.

A. Summary

Maintenance activities during this nine month period saw emphasis on subarray inspection, preventive maintenance at both LMC and LDC, shop checks and repair of SEM and SP equipment, repair of mechanical assemblies at LDC, installation of an LP Develocorder, an antenna study for WWV receiver, and training.

A summary of the total maintenance activity is given in Table XIII where the number of work order actions in the LMC, LDC, and utility areas are shown. The 725 completed work orders represent 976 separate and traceable actions by the maintenance activities and since several repair actions may result from the clearing of one particular trouble, the number of maintenance actions can exceed the number of work orders. The work orders do not indicate the man-hours involved but are indicative of the

work load. The system work orders completed consisted of 356 preventive maintenance routines, 179 corrective maintenance, one modification, one special test, and 101 utility actions. A total of 78 items of equipment were repaired in the LMC and LDC shops. The backlog in the shop of 28 items will be repaired during the winter months.

B. Data Center

Five systems maintained at the LDC are the IBM-360/44 Computer, the DEC PDP-7 Computer, the Digital, the Analog, and the Test and Support.

A total of 298 work orders were completed for 470 maintenance actions plus 5 card repairs in the shop. Table XIV provides a breakdown of the LDC maintenance actions by system and month. A total of 93 man-hours were spent on training on the LDC equipment.

1. System 360

The maintenance responsibility for the IBM 360/44 is handled locally with assistance from IBM as needed. The LDC 360 system consists of (1) a 2044-G Processing Unit, (2) a 1052-7 Printer/Keyboard, (3) a 2501-B1 Card Reader, (4) an 1827-1 Data Control Unit (5) an 1826 Data Adapter Unit, and (6) a 2701-1 Data Adapter. During this period there were eleven repairs on the system and 25 preventive maintenance actions.

The 1052 unit overhauled by IBM was installed in February and the lease terminated on the IBM unit. Of the 11 system failures during this period 7 were caused by the 1052. A tilt tape, the type ball, the C7 contacts, and the Carrier Return

TABLE XIII

SUMMARY - WORK ORDERS

JANUARY - SEPTEMBER 1976

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
LMC				
SYSTEM -A	1	250	251	0
SUBASSEMBLY-B	32	46	72	6
COMPONENT -C	0	5	3	2
TOTALS	33	301	326	8
LDC				
SYSTEM -A	8	294	293	9
SUBASSEMBLY-B	0	3	0	3
COMPONENT -C	17	5	5	17
TOTALS	25	302	298	29
UTILITY	14	88	101	1
COMBINED TOTALS	72	691	725	38

TABLE XIV

DATA CENTER MAINTENANCE ACTIONS

JANUARY - SEPTEMBER 1976

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
360										
CORRECTIVE	0	2	2	1	1	0	1	1	1	11
PREVENTIVE	0	6	3	3	3	2	0	5	3	25
PDP-7										
CORRECTIVE	4	4	1	5	3	6	4	1	10	38
PREVENTIVE	23	24	25	26	24	22	20	28	25	217
DIGITAL										
CORRECTIVE	0	0	1	1	0	0	3	2	1	8
PREVENTIVE	4	9	5	4	8	5	4	9	5	53
ANALOG										
CORRECTIVE	4	1	2	0	2	3	3	2	1	18
PREVENTIVE	0	5	0	0	6	0	0	5	0	16
TEST AND SUPPORT										
CORRECTIVE	3	3	8	5	3	7	7	2	4	42
PREVENTIVE	4	0	6	3	3	7	3	2	4	32
TOTALS	42	54	53	48	52	55	45	57	54	460

Interlock Contacts were replaced as well as adjustments of the print shaft, C7 cam, and escapement linkage.

The sealed bearings failed and were replaced in the fan motor used for core stack cooling. This problem was corrected before any heat damage could occur to the CPU.

An intermittent trouble resulting in occassional power drop out of the 2501 and 2701 cleared itself after power cycling the system several times. Inspection of K24 stepping switch contacts did not show any evidence of dirty contacts. It is suspected dirty contacts "self-cleaned" after repeated cycling of K24.

Two CPU failures resulted in extended downtime, both troubles occuring during three-day holiday weekends. A 5800516 card failed in location 1A-C4C4 that caused a continuous "priviliedged operation" condition in the CPU not allowing any other instructions to be completed thus halting the system. The other failure was caused when the "Invalid OP Decode" circuit stopped machine operation with a continuous "Invalid Operation condition. Extensive trouble shooting by LDC and IBM tecnnicians failed to find the source of the problem. Operation was restored by installing a modified 5803350 card in location 1AC4E4 which allows legitimate "Invalid Operation" conditions to stop the machine but eliminates the continuous level. Trouble shooting will continue on this problem on a non-interrupt basis of the system operation.

The system operated without any troubles during January and May of the nine month period.

2. PDP-7 System

Maintenance of the LDC's PDP-7 computer system includes the peripheral equipment as well as the basic CPU. These devices include (1) a Burroughs Card Reader, (2) a KSR-35 Teletypewriter, (3) four MA1 SC 7296 Magnetic Tape Drives, (4) a Versatec LP-1150 Line Printer, (5) a Data Control Unit, (6) a Serial Output Unit, and (7) a Paper Tape Reader-Punch.

There were 38 repairs on this system and 217 preventive maintenance routines completed. The repair distribution was: tape units, 16; teletypewriter, 5; lineprinter, 4; card reader, 4; paper tape reader, 2; and paper tape punch, 1. Most of the troubles were routine adjustments and replacement of bulbs and worn mechanical parts.

Two failures in the CPU required extensive trouble shooting. A bad wire connection in the Extended Memory Control unit would not allow transfer of program data preventing normal operation. A bad L1 coil on a 4407 card in 3E1 of the tape controller prevented recording of data at the normal 800 characters per inch (CP1).

Failures in a tape unit (MA1 SC 7296) required card repairs. A short in the capstan drive circuits in tape unit #8 required repairs to cards J6, J7, J10, and J11. At a later date this unit would not "write" due to a faulty "IC" component on the Write/Enable Card.

An apparent teletypewriter failure required replacement of a bad 4407 card in the KSR-35 interface circuit in the CPU.

3. Other LDC Systems

The other systems maintained at the LDC are the Digital, Analog, and Test and Support Systems.

The Digital System includes the PLINS, MINS, two identical timing cabinets, and the inverter operated power system. There were 8 repairs and 53 preventive maintenance routines performed on this system during this period. The repairs were two TOD adjustments, two TOD clock equipment checks, replacement of a bad K2 in the power Control Drawer, replacement of lamp in the inverter meter relay, and two corrections in the Scope Outputter affecting telemetry and analog output.

The cabling between the two identical timing cabinets was modified and rerouted to simplify operational change between the two redundant systems. It will now be easier and quicker to switch LASA timing from one cabinet to the other for preventive maintenance and to correct for malfunctions.

The Analog System covers the 96-channel D/A conversion equipment, the D/A patch panel, the analog timing equipment, the WWV receiver, and Develocorders. Completed were 16 preventive maintenance routines and 18 troubles corrected. Out of 18 troubles, 13 were minor repairs to Develocorders except for replacement of one film drive motor. The other five were repairs to analog timing clocks, Develcorder rack, and the 16 channel recorder.

In September a frequency division multiplex system was installed for the Albuquerque Seismological Laboratory (ASL). The telephone line was installed by the local telephone company

and existing cabling and space was used in the analog racks. The cabling was formerly used for a similar Lincoln Laboratory system. The ASL is now receiving 3 signals from LASA. Any sensor is available through the analog patch panels.

Since major construction to the telephone company building to the south of the LDC building, we have experienced problems with a weak and intermittant fading WWV signal. Following a study of the situation, we have concluded that more signal capture area and more vertical height of our antenna are needed to clear the telephone building shadow zone. We determined that fading is peculiar to our physical location and that 5 MHz is the most reliable. We are now constructing a one-half wave 5 MHZ vertical helix-wound antenna that will be installed on an existing 65 foot tower on the roof of the LDC building. The antenna is being made by LDC personnel using fiberglass construction and will be for receiving only.

Film recording of LP data from two subarrays at a time started in February. New subarrays are recorded each week and films reviewed for LP system problems.

The Test and Support System encompasses not only the two Maintenance Display Consoles (MDC) but all other equipment for the support of the data center's operation such as the environmental equipment (air conditioners, electrostatic air filters) and the film viewers and copiers. Of 74 maintenance actions on this system, 42 were corrective and 32 were for preventive maintenance routines. Of the 42 corrective repairs, 29 were routinely expected bias battery replacements in the MDC units.

The only major failure was the blower assembly for

the 15 ton rooftop air conditioner used for the computer room. A sealed bearing froze on the squirrel cage shaft causing the sheet metal mount to tear. The complete assembly had to be removed from the roof, the housing welded, new bearings installed on the shaft and the assembly re-installed. The blower motor bearings were replaced while the system was down.

C. Maintenance Center

The LMC supports the LASA operation with both array activities and shop testing and repairs.

The systems maintained by LMC are the SP, LP, SEM, Power, and Weather Station.

The personnel at LMC completed 326 work orders representing 405 separate maintenance actions plus 72 items repaired in the shop. The array work orders included 64 corrective maintenance, 183 preventive maintenance, one modification, and one special test.

1. Array Activities

Table XV shows the array maintenance actions by system and month required to support the LASA during this 9 month period. To accomplish this maintenance, 197 visits to CTH's and 22 visits to WHV's were made during the period. This was done with 154 trips to the field plus 5 trips to the Malmstrom AFB PMEL covering a total of 19,460 miles.

The field repairs were all of the expected type that includes RA-5 Amplifier and HS-10-1A Seismometer replacements and adjustments of channel levels and offsets.

All of the subarrays were visited and checked during

the winter although the Snowcat was used extensively during January. In February the roads were very muddy curtailing much of the field activity.

The spring melt of snow was very gradual and there was no damage in the vaults from water. There were no incidences of lightning damage to the equipment this spring and summer. The subarray vaults and well-head vaults were in good condition and dry at the end of the summer season.

Large portions of land in the array have been plowed by the landowners to plant wheat. Contour plowing was not used and all roads, trails, creekbeds, and gulleys were plowed over and filled in these areas. Although we still maintain our right-of-ways in these areas; we anticipate difficulty in reaching certain WHV's and CTH's when the ground becomes wet during this next winter and spring.

2. Shop Activities

The extent of the shop work is summarized in Table XVI. Shop activity is minimal during fair weather when most activity is centered in the field. When travel conditions limit field work, maintenance activity is consentrated on the shop repairs.

During the winter the backlog items will be repaired plus checking of stand-by units not used within the last year. Particular attention is being given operation at environmental temperatures utilizing the LMC Environmental Chamber for all adjustments and checkouts.

TABLE XV

ARRAY MAINTENANCE ACTIONS

JANUARY - SEPTEMBER 1976

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
SP										
CORRECTIVE	1	0	3	1	6	4	7	6	1	29
PREVENTIVE	13	13	14	21	19	14	13	13	13	133
LP										
CORRECTIVE	2	3	1	1	1	1	4	1	1	15
PREVENTIVE	0	0	0	0	0	0	0	0	0	0
SEM										
CORRECTIVE	2	0	2	6	1	3	0	3	0	17
PREVENTIVE	4	3	6	4	3	5	5	3	12	45
POWER										
CORRECTIVE	1	0	3	1	0	1	0	0	0	6
PREVENTIVE	4	3	6	4	3	5	5	3	12	45
WEATHER STATION										
CORRECTIVE	0	0	0	0	0	0	0	0	0	0
PREVENTIVE	0	0	0	0	0	0	1	0	0	1
TOTALS	27	22	35	38	33	33	35	29	39	291

TABLE XVI

EQUIPMENT SHOP REPAIR SUMMARY

JANUARY - SEPTEMBER 1976

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTALS
SEM ASSEMBLIES	1	9	7	0	1	3	0	0	0	21
SP ASSEMBLIES	15	16	1	2	0	0	8	4	1	47
LP ASSEMBLIES	0	0	0	0	0	0	0	0	0	0
POWER ASSEMBLIES	0	0	1	0	0	0	0	0	0	1
OTHER ASSEMBLIES	0	0	2	1	0	0	0	1	0	4
CARD REPAIRS	1	0	0	1	0	2	2	0	0	6
TOTALS	17	25	11	4	1	5	10	5	1	79

All 79 repairs were made at LMC except for five at the LDC. Of the 47 SP assemblies repaired, 36 were RA-5 amplifiers, 9 were HS-10-1A seismometers, and 2 were RA-5 power supplies. The 21 SEM assemblies repaired or checked were 8 Input Drawers, 5 MUX units, 4 Output Drawers, and 4 PDC Drawers.

D. Facilities Support

LASA operations are supported by the facilities and vehicles available. These both require attention for their continued provision and maintenance. The land required for the array's CTH, LPV, and WHV structures as well as the buildings housing the LDC and LMC are essential. Insuring proper operating vehicles used for travel between facilities requires maintenance support.

1. Land Provision

Provision of the land for the array requires 50 leases. In the interest of good relations with the landowners, 82 contacts were made to deliver lease checks, discuss subarray access trails, and other matters concerning the land use.

There was only one location with drilling activity within the array that could affect seismic data. A well was drilled in January, $1\frac{1}{4}$ miles from sensor 82 at Subarray C2. Plowing of land within the array was extensive all summer during daylight hours.

2. Land and Facilities Maintenance

The amount and type of utility work orders engaged in during this period for the LMC is shown in Table XVII. The 101 completed work orders show 65 for actual repairs, 18 for facility

TABLE XVII

SUMMARY - UTILITY WORK ORDERS

JANUARY - SEPTEMBER 1976

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
CABLE TRENCH AND TRAIL INSPECTION	13	2	15	0
CABLE TRENCH BACKFILL	0	1	1	0
WHV SITES LANDSCAPED	0	21	21	0
MARKER POST OR WHV COVERS REPLACED	1	3	4	0
CTH MAINTENANCE	0	29	28	1
VEHICLE MAINTENANCE INSPECTION	0	18	18	0
FENCE INSPECTION	0	3	3	0
TRAIL REPAIRS	0	0	0	0
LMC FACILITY MAINTENANCE	0	11	11	0
TOTALS	14	88	101	1

inspections, and 18 for vehicle maintenance/inspections.

The LMC facility was inspected in January by the local power company and found all heaters and venting to be satisfactory. All heaters were serviced and the landlord replaced some deteriorated sidewalk in front of the building.

The access to subarray AO has been regraded and surfacing improved. This trail had washed out and was difficult to negotiate. The cable trench was refilled between WHV's 51 and 71 at subarray D3 where cables were exposed by runoff. A small dam was made to divert future runoff away from the trench.

3. Vehicles

Aeronutrontic Ford provides three pick-up trucks for use at the LMC by the field crews and land agent and a Station Wagon for administrative/field inspections at the LDC. The trucks (two 1974, F113 models and one 1970 F110) are equiped with four-wheel drive and are specially prepared for travel over rough trails and use at the array sites. Minor vehicle service and inspection is provided by the LMC for the trucks.

The government provides a fork-lift and a snow tractor. The LMC personnel serviced these vehicles (lubrication and oil changes) and no further maintenance was required for this period.

The mileage driven during this period in support of the LASA totalled 19,460 miles without any accidents.

R. Townsend

SECTION VI

ASSISTANCE PROVIDED TO OTHER AGENCIES

A. Seismic Data Analysis Center (SDAC)

The LASAPS processor is operated at the LDC 24 hr/day and 7 days/week to provide real time array data on line to SDAC. The weekly near-regional reports with events and blasts within 20° of the array center are also distributed to SDAC.

B. National Earthquake Information Service (NEIS)

The LDC provides NEIS with the weekly reports of near-regional events and blasts, responds to their telephone requests for selected event information, and operates an FM telemetry link for transmitting data from three selected SP seismometer channels.

C. MIT Lincoln Laboratory

The periodic near-regional reports with the strip-mine blast supplements are distributed to Lincoln Laboratory.

D. Montana Department of State Lands

The strip-mine blast supplement to the near-regional reports is mailed to the Dept. of State Lands in Helena, Montana.

R. Matkins

SECTION VII

DOCUMENTATION DEVELOPED

A. Technical Reports

The following reports were prepared and distributed during the final nine months of this project:

1. "Montana LASA Operation Report for January 1976" T/R 2126-76-76, 9 FEB 1976.

2. "Montana LASA Operation Report for February 1976" T/R 2126-76-77, 9 MAR 1976.

3. "Montana LASA Operation Report for March 1976" T/R 2126-76-78, 6 APR 1976.

4. "Montana LASA Operation Report forApril 1976" "T/R 2126-76-79, 7 MAY 1976.

5. "Montana LASA Operation Report for May 1976" T/R 2126-76-80, 7 JUN 1976.

6. "Montana LASA Operation Report for June 1976" T/R 2126-76-81, 7 JUL 1976.

7. "Montana LASA Operation Report for July 1976" T/R 2126-76-82, 5 AUG 1976.

8. "Montana LASA Operation Report for August 1976" T/R 2126-76-83, 5 SEP 1976.

9. "Montana LASA Operation Report for September 1976" T/R 2126-76-84, 5 OCT 1976.

B. Technical Correspondence

1. Ltr to Capt. Woodward. "Master Edit Tape Header" 21 MAY 1976.

C. LASA System Manuals

The LASA System Manuals are being revised as described in Reference 1. Progress on manual revisions depends upon the level of activity necessary for other tasks and varies with each of the ten manuals involved.

R. Matkins

CONCLUSIONS

1. Operation of the new LASAPS over the 4800-baud line is not as satisfactory as with the previous system, especially in the area of operator communications.

2. Continuous (almost full time) digital recording of array data can be performed using the LIARS format without interferring with other PDP-7 computer functions. This mode is preferred over the standby/back-up operation previously used.

3. Auto edit digital recordings can be a source of array data for events of interest beyond the 60-day retention cycle of LIARS recordings.

4. No decline in the performance of the Montana array systems has been observed.

5. Daily teleseismic event processing at the LDC is an important part of the array operation.

RECOMMENDATIONS

Based on the operation of the Montana array and data center during this contract period, we recommend the following:

1. That the local study of the daily teleseismic event reports be continued and that the Montana array be considered as the source of seismic event information not available over the 4800 baud line.

2. That the LASAPS/SDAC data communications be reviewed to insure the new LASAPS is operating as intended by the original design.

3. That the telephone attached to 4800 baud data set be equipped with greater ringing power.

REFERENCES

1. Matkins, R. "Montana LASA Semi-Annual Technical Report" T/R 2126-76-75. Aeronutronic Ford, Billings, MT 23 JAN 76.

2. IBM. "Ninth Quarterly Technical Report" ISRSPS ESD-TR-72-122 NOV 1970, pp 21-52.

APPENDIX

MONTANA LASA CONFIGURATION

The LASA configuration was reduced in size at the start of 1974 to consist of the inner thirteen subarrays within the D-ring as shown in Figure A-1. LASAPS data was reformatted to use only the ten-innermost of the 16 sensor signals telemetered from each subarray to the LDC. The sensors now in operation are indicated in Figure A-2. At subarray D2, six additional SP signals are developed from the three-component instrumentation installed at the center hole location 10; these are the three standard gain and three padded outputs from the vertical, north-south and east-west horizontal seismometers.

Three component LP signals from the outer nine subarrays of the array and three-component padded signals from subarray C2 are collected and formatted within the LASAPS processer for transmission to SDAC.

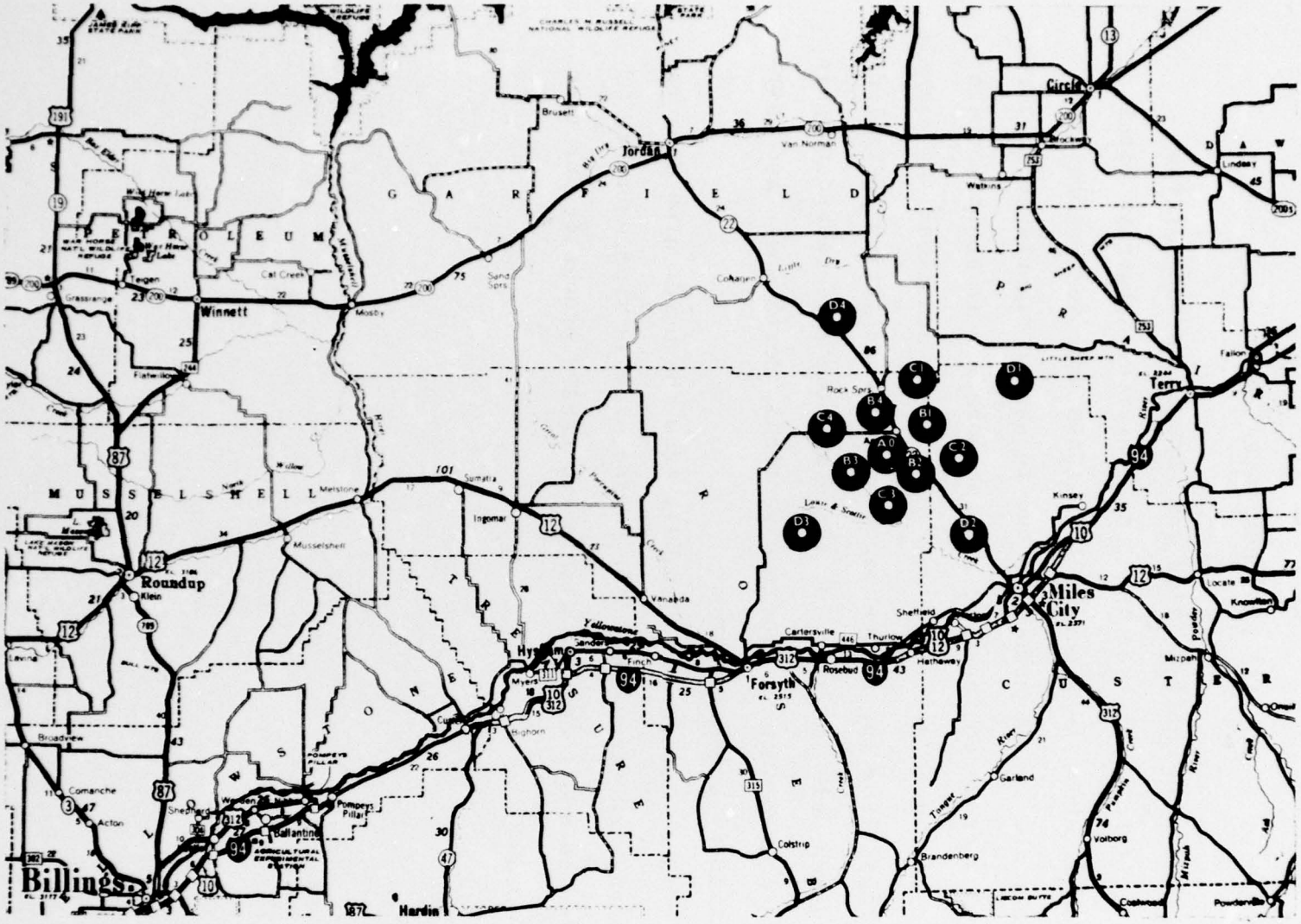
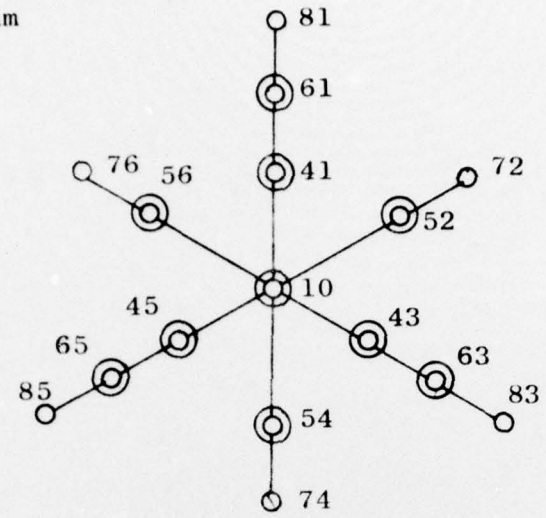
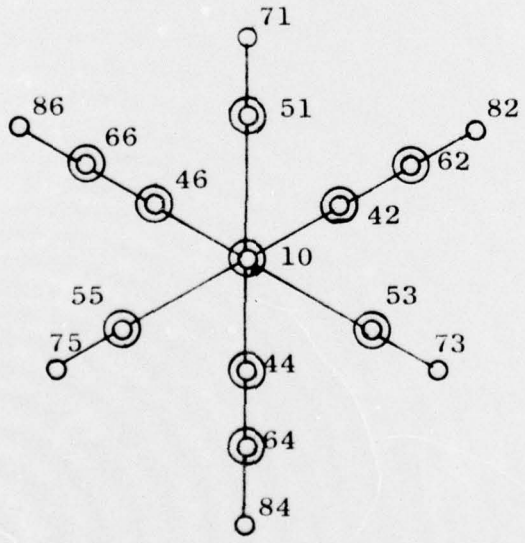


Figure A.1 Montana LASA

◎ Indicates sensor used in the LASAPS Sum



Subarrays AO, C4, D1, D3, D4



Subarrays B1, B2, B3, B4, C1, C2, C3, D2

Notes:

C1-hole 51 plugged, sensor 71 used in LASAPS sum.

D2-hole 10 develops six additional signals for use in LASAPS, i.e. Z, N/S, E/W and attenuated Z, attenuated N/S, attenuated E/W.

Figure A-2 Subarray SP Sensor Configurations